Thermal Conductivity

In-class Presentation - AER373 Solid Mechanics

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Outline

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Definition

Thermal Conductivity

- **Conduction**: energy transfer from the more energetic particles of a substance to the adjacent less energetic ones as a result of interactions between particles.
- In physics, **thermal conductivity** is rate of heat transfer through a unit thickness of the material per unit area per unit.
- It is often denoted k or λ.
- It is a property of material to conduct heat.
- It influences heat transfer rate.

Definition

Unit Dimension

- **Unit**: In SI units, it is measured by (W/mK).
- **Dimension**: $\frac{M \cdot L}{T \cdot \Theta^3}$

Definition

Fourier 's Law

- Heat conductivity influences heat transfer rate and the relationship is given by Fouriers Law in the following form: $\dot{q} = -k\frac{\mathrm{dT}}{\mathrm{d}x}$
- rate of heat transfer per unit surface area equals to minus heat conductivity times temperature gradient
- 1-Dimensional form
- $\dot{q}$ is heat flux
- $\frac{\mathrm{dT}}{\mathrm{d}x}$ is temperature gradient
- Similar to Ficks Law for mass diffusion: $J = -D\frac{\mathrm{d}\Phi}{\mathrm{d}x}$

Outline

Dimensionless Number

1. **Prandtl Number** Pr: $Pr = \frac{\mu_p}{k}$
2. **Biot Number** Bi: $Bi = \frac{h \cdot L_c}{k}$
3. **Nusselt Number** Nu: $Nu = \frac{h \cdot c_p}{k}$

Outline

Factors that influence Thermal Conductivity

Temperature

- $Gas : k \propto \frac{1}{T^{\frac{1}{2}}}$
- **Liquid**: $k \propto \frac{1}{T}$ except water!!! For water, $k_{water} \propto T$
- **Alloys**: k increases w.r.t T
- **Pure Metals**: k almost constant

Factors that influence Thermal Conductivity

Material Structure

- Pure crystalline substances can exhibit different thermal conductivities along different crystal axes.
- Sapphire, k = 35 W/(mK) along the one axis and 32 W/(mK) along another axis.
- In anisotropic materials, k typically varies with orientation; can be represented by a second-order tensor.
- In non-uniform materials, k varies with spatial location.

Outline

Thermal Conductivity Table

- In general,
  $Diamond(2300) > Metal > CrystallineSolid(100 \sim 10) > AmorphousSolid(1) > Liquid(0.1) > gas(0.01)$
- More Precisely

Thermal Conductivity Table

Material	Thermal Conductivity (at room temp)
Air	0.024
Pure Aluminium	204.3
Argon	0.016
Brick	0.15
Carbon Dioxide	0.0146
Pure Copper	385
Natural Diamond	2200
Glass	0.8
Pure Gold	314
Nitrogen	0.0234
Paper	0.05
Rubber	0.16
Pure Silver	406
Steel with carbon	36
Water	0.563

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Heat Sink

Heat sink is a passive heat exchanger that cools a device by dissipating heat into the surrounding medium.

Most common materials for heat sinks are aluminum alloys.

Copper is also widely used.

Heat Sink

Prevent overheating of computer processor.

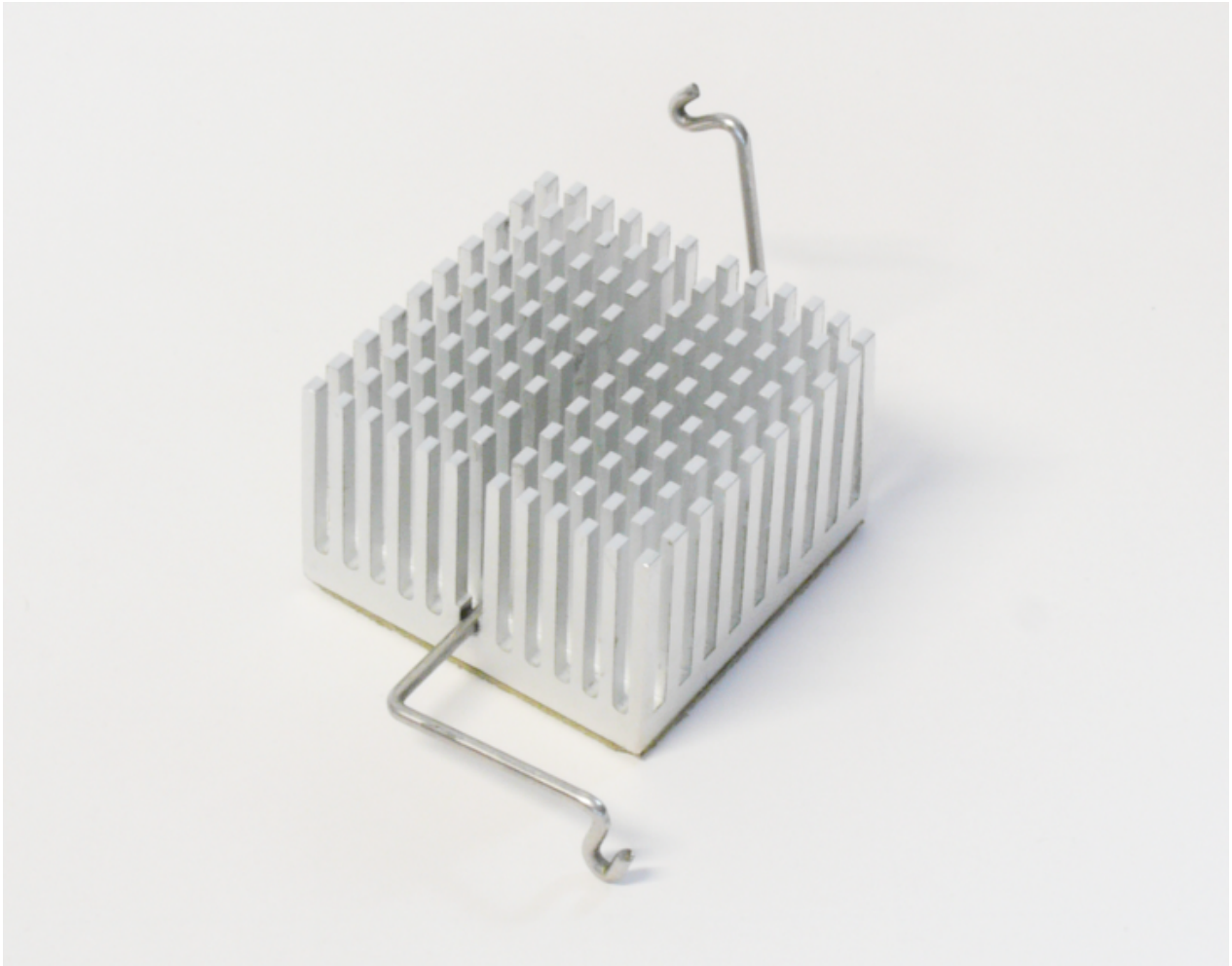

Figure: heat sink

For Further Reading of Interest I


Y. A. Cengel.
Introduction to Thermodynamics and Heat Transfer.
McGraw Hill, 2005.


E. A. Mason S. C. Saxena.
Approximate Formula for the Thermal Conductivity
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